

Advanced imaging for Biomedical Applications



Presentation

Prerequisites

- Basics of wave physics
 - Basics of geometrical and wave optics
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Learning objectives

Students will understand the challenges related to optical imaging of living tissues and will have acquired scientific culture in basic and advanced microscopy techniques. They will be able to perform back-of-the-envelope calculations for optical systems and will develop a systematic approach to study and understand new imaging techniques. They will also be able to grasp the challenges of deep imaging in scattering tissues, and the basics of the laser light-matter interaction for diagnosis and therapy. Ultimately, they will be capable of providing scientific advice to biologists on the selection of appropriate imaging modalities for their research needs.

Description of the programme

This course is structured around two complementary approaches to advanced optical imaging of biological systems. The first part covers advanced microscopy techniques and their physical principles, exploring how different optical contrasts and imaging modalities can reveal biological structures and processes. The second part addresses the fundamental challenge of light propagation in complex biological media and develops physical models and computational approaches for deep-tissue optical imaging and laser light tissue interaction for optical diagnosis/therapy.

I - Advanced Microscopy (Pascal Berto)

This course introduces advanced biological microscopy concepts, starting with intrinsic optical contrasts such as absorption, scattering and phase signals. It then explores fluorescence-based imaging, from confocal setups to super-resolution techniques, and highlights vibrational microscopy for label-free chemical mapping. Finally, several methods for deep-tissue imaging are introduced, including light-sheet and multiphoton microscopy as well as adaptive optics and optical clearing.

II - Diffusion (Julien Fade):

In this course, we will explore some physical modeling approaches in order to describe and predict propagation of light in complex media. We will show how the optical scattering phenomenon, which takes place in biological tissues (but also more generally when light propagates in atmosphere, turbid water, or astronomical objects...) can be statistically modeled and ruled by the Radiative Transfer Equation of the photon flux in scattering media. The last part of the course will be dedicated to the application of such models to deep tissue "diffuse optical imaging", relying on a numerical image reconstruction process (inverse problem solving), with a number of applications in biomedical optical diagnosis/therapy, and to the basics of laser light-tissue interaction allowing diagnosis and optical therapy.

Bibliography

V. V. Tuchin, Tissue Optics: Light Scattering Methods and Instruments for Medical Diagnostics, Third Edition, SPIE Press, 2015

F. Martelli, et al., Light Propagation through Biological Tissue and Other Diffusive Media: Theory, Solutions, and Validation, SPIE Press, 2023

L. Zuppiroli, M.-N. Bussac, Traité des couleurs, Presses Polytechniques et Universitaires Romandes (PPUR), 2001

Teaching team

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Total des heures

0h